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2D PIC modeling of the EUV induced hydrogen plasma and comparison to the observed carbon etching rate

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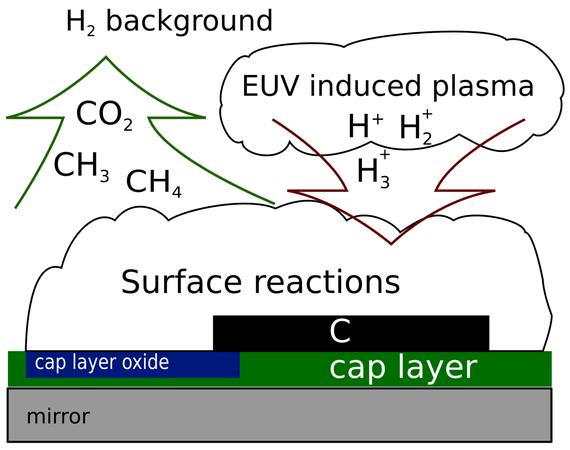
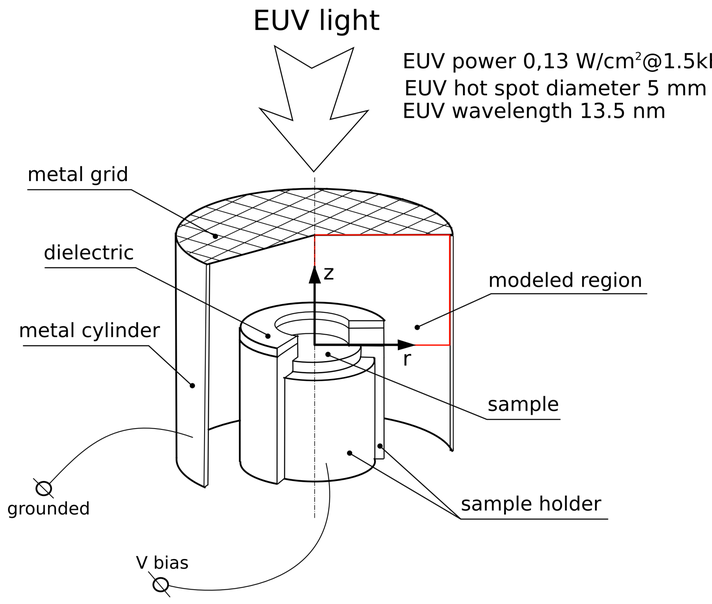
1 Introduction

Extreme Ultra Violet (EUV) radiation
- degradation of mirror optics
- plasma formation on top of mirror



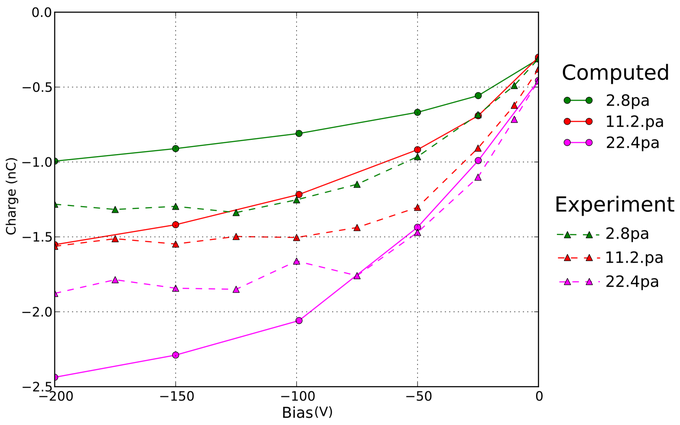
Non destructive on line cleaning by EUV generated plasma
- Knowledge of ion fluxes to surface is required to estimate surface carbon cleaning rate.
- A particle in cell plasma model was developed to simulate these fluxes

2 Experiment overview



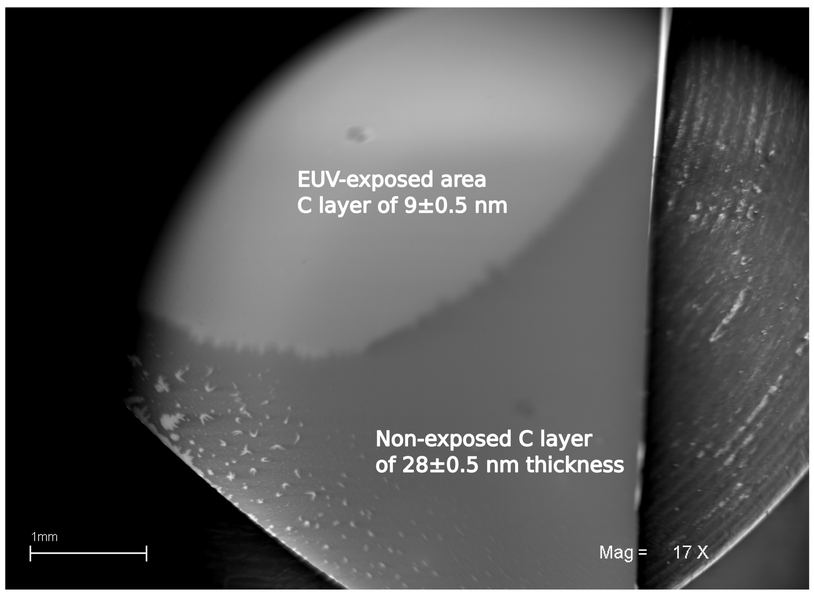
2.1 Experimental charge-bias characteristics

The charge-bias characteristic was used to to normalize the EUV intensity and to check the model quality



charge passed through the system per pulse

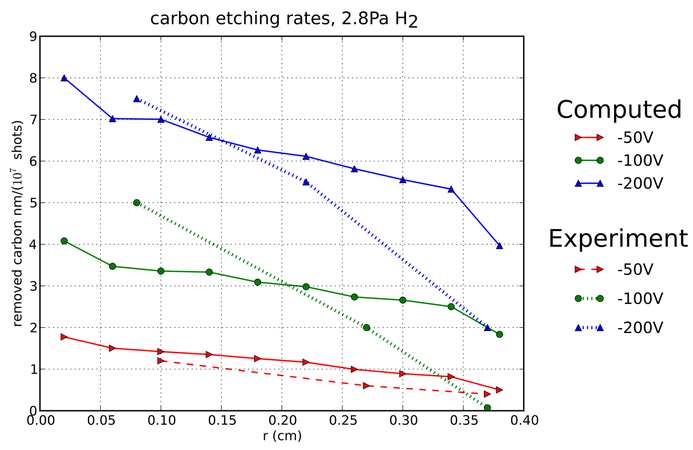
2.2 Carbon EUV induced etching



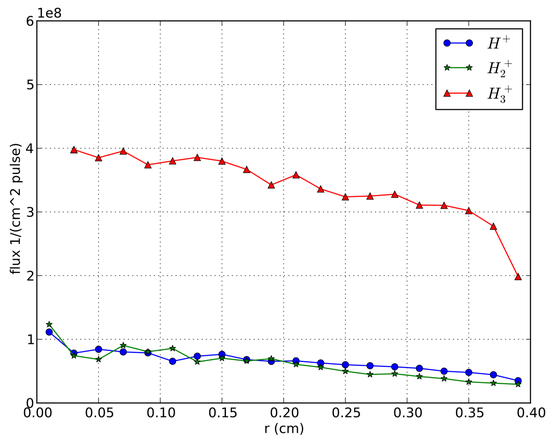
Typical SEM image of C layer area cleaned by EUV-induced plasma in ISAN experiment at 0.65 Torr H2, sample biasing at -100V and 10^7 shots with 0.2 W/cm^2 EUV radiation power. The sample consists of magnetron deposited carbon on Si substrate.

The H_2 pressure range (2.8Pa, 11.2Pa, 22.4Pa, 45Pa) was experimentally scanned.

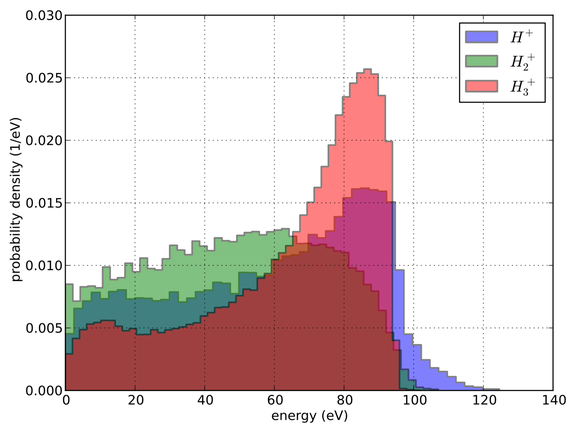
3 Modeling



Comparison of observed and computed carbon etching rates for different biases at 2.8Pa H_2



Computed ion flux to the sample per pulse (-100V bias, 2.8Pa H_2) integrated over energy



Energy distribution function of the ion flux to the sample (-100V bias, 2.8Pa H_2) integrated over sample surface

■ 2D PIC modeling was performed for 2.8Pa, 11.2Pa, 22.4Pa hydrogen

■ plasma model includes
- ► spectrum of EUV source
- ► photo-electron emission
- ► ionization of background gas by photons and electrons
- ► hydrogen ions chemistry

■ the carbon etch rate was obtained from computed ion fluxes, etch yield (carbon atom per ion) was taken as:

$$Y_{ion} = C_f \sqrt{E_{ion} \times N_H}$$

where N_H is number of H atoms in ion and constant C_f was determined from the fit to the experimental data

$$C_f = 0.06\ 1/\mathrm{eV}$$

■ Note that for 100 eV H_3^+ ion this means that the etching rate is about one carbon atom per incoming H_3^+ ion, thus some chemical processes occur on the sample surface.

4 Conclusion

Comparison of the carbon etching rates observed at various experimental conditions and estimated from computed ion fluxes for the same conditions suggest that etching of carbon under EUV is chemical sputtering or reactive ion etching of carbon.

5 Acknowledgments

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